Title	Functional visual fields: relationship of visual field areas to self-reported function
Running head	Functional visual fields
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Abstract

Purpose

The aim of this study is to relate areas of the visual field to functional difficulties to inform the development of a binocular visual field assessment that can reflect the functional consequences of visual field loss.

Methods

52 participants with peripheral visual field loss undertook binocular assessment of visual fields using the 30-2 and 60-4 SITA Fast programs on the Humphrey Field Analyser, and mean thresholds were derived. Binocular visual acuity, contrast sensitivity and near reading performance were also determined. Self-reported overall and mobility function were assessed using the Dutch ICF Activity Inventory.

Results

Greater visual field loss (0-60 deg) was associated with worse self-reported function both overall (R^2=0.50; p<.0001), and for mobility (R^2=0.64; p<.0001). Central (0-30 deg) and peripheral (30-60 deg) visual field areas were similarly related to mobility function (R^2=0.61, p<.0001 and R^2=0.63, p<.0001 respectively), although the peripheral (30-60 deg) visual field was the best predictor of mobility self-reported function in multiple regression analyses. Superior and inferior visual field areas related similarly to mobility function (R^2=0.56, p<.0001 and R^2=0.67, p<.0001 respectively). The inferior field was found to be the best predictor of mobility function in multiple regression analysis.

Conclusion

Mean threshold of the binocular visual field to 60 deg eccentricity is a good predictor of self-reported function overall, and particularly of mobility function. Both the central (0-30 deg) and

peripheral (30-60 deg) mean threshold are good predictors of self-reported function, but the peripheral (30-60 deg) field is a slightly better predictor of mobility function, and should not be ignored when considering functional consequences of field loss. The inferior visual field is a slightly stronger predictor of perceived overall and mobility function than the superior field.

Introduction

The functional consequences of visual field loss are known to include diminished mobility,[1-3] diminished ability to complete activities such as reading or watching television,[4] and an increased risk of falling.[4-6] Binocular visual field assessment is thought to represent functional abilities better than monocular assessment, especially in individuals with visual impairment, as most activities of daily living are usually performed with both eyes open.[7-10] However, there is no standard reference method for assessing binocular functional fields. Currently available conventional visual fields tests are designed to detect and monitor the progression of disease, and no visual field test currently available is optimised for reflecting the functional consequences of visual field loss. Although there are numerous studies that relate self-reported function[11-27] or performance[28-34] to visual field parameters, few do so with the intention of developing a clinically applicable method of functional field assessment.

Development of a binocular visual field test that can reflect functional difficulty would be a valuable tool in low vision assessment. Quantification of visual field loss with an understanding of how scores relate to functional difficulty would be helpful not only in assessing and managing the low vision patient, but also in determining robust criteria for visual impairment registration as compared to visual field criteria currently in place in the UK that are open to significant subjective interpretation.[35]

Previous studies have related visual field loss to function,[11-33] but many of these have used conventional monocular visual fields tests that do not reflect the binocular field,[11,12,15-20,28] or have assessed the visual field using monocular threshold tests to construct a binocular field plot.[14,21] Of the studies that have assessed the visual field binocularly, the majority have assessed the visual field out to 30 deg.[13,30] Those studies that have assessed the binocular visual field past 30 deg have used kinetic[27,29,31,32,34] or suprathreshold test strategies such as the Esterman visual field test.[22-26] Threshold sensitivities of the peripheral visual field have not previously been determined.

The current study builds on previous work that used a threshold paradigm to assess the binocular visual field out to 30 deg and found that mean thresholds can predict self-reported overall and mobility function.[13] However, it is not known if testing the visual field past 30 deg is of further benefit. Furthermore, numerous studies have suggested the particular significance of the inferior visual field for mobility function,[28,29,36-39] and inferior visual field loss has been shown to impair mobility performance[28,29,39] and perceived mobility function,[36] increase postural sway,[37] and increase the risk of falling[37,38] in individuals with no visual impairment,[28,38] with early visual field loss,[36,37] or with simulated field loss.[39] It is not known whether the inferior field remains more significant to mobility function in individuals with a greater degree of visual field loss. The importance of the inferior visual field to overall self-reported function is also unclear.

The current study uses a binocular threshold test to extend the findings of Tabrett and Latham[13] and assesses the visual field out to 60 deg to determine whether the functional visual field would benefit from being assessed beyond 30 deg from fixation, and to test the significance of the inferior field to mobility function in a sample of individuals with moderate to severe visual field loss. Findings will be used to aid the design of binocular functional field test that assesses important areas of the visual field, as a potential clinical tool for the low vision assessment.

Methods

Participants with self-reported peripheral visual field loss were recruited. Individuals with conditions not primarily affecting peripheral visual function, such as macular degeneration, were excluded from the study, along with those under 18 years old and those unable to perform verbal evaluations in English. Ethical approval was granted by Anglia Ruskin University Faculty of Science and Technology Research Ethics committee. The tenets of the Declaration of Helsinki were upheld. All participants gave informed consent after the nature of the study was explained. All data collection was conducted by one experienced optometrist.

A face to face interview elicited demographic characteristics (Table 1). The Dutch ICF Activity Inventory (D-AI)[40,41] was used to determine self-reported function in Activities of Daily Living, since it covers a wide range of goals relevant to people with peripheral visual field loss.[43] The original questionnaire assesses the difficulty of 47 rehabilitation goals, nested within 9 domains of the World Health Organisation International Classification of Functioning framework.[42] In the current study, participants were asked to grade their perceived level of difficulty for 43 goals. These represented the 47 goals proposed by Bruijning et al[40] but excluded the two goals underpinning the 10th emotional health domain, and a further two relating to driving and riding a bicycle that have been shown not to fit the unidimensional construct of the questionnaire in people with peripheral vision loss.[43] Respondents could indicate that a goal was not important or not applicable to them, which was scored as missing data. If the goal was relevant, difficulty was rated on a 5 point Likert scale (none, slight, moderate, very difficult, impossible). Responses to the four goals of the mobility domain (mobility at home, mobility indoors, mobility outdoors, and using public transport) were used to determine self-reported mobility function.

High contrast distance visual acuity was assessed binocularly and scored by-letter with participants' habitual distance spectacle correction using a 3m internally illuminated ETDRS logMAR chart.[44] If the largest letters could not be read at 3m, the chart was moved 50% closer to the participant to 1.5m and 0.75m. MNRead charts were used at 40cm to determine binocular clinical reading performance with habitual near spectacle correction or a distance correction with +2.50 reading addition where appropriate.[45,46] Participants with acuity that was not measureable but with perception of light were assigned distance and near reading acuities of 3.00logMAR.[47] Contrast sensitivity was measured binocularly with participants' habitual distance spectacle correction using a Pelli-Robson Chart[48] at 1m scored on a letter by letter basis.[49] Participants with no measurable CS function were assigned a score of 0.00logCS.[47]

Binocular visual field assessments were performed using the Humphrey Field Analyser[50] utilising the monocular test strategy for the right eye with a standard size III Goldmann white target. The chin rest was positioned as far right as possible and the left hand side of the chin rest was used. Since implementing monocular tests binocularly using the HFA invalidates conventional methods of fixation monitoring[51] participant's fixation was monitored manually.[13,30,52] Other reliability indices provided by the HFA, including false positives and false negatives, were also reviewed. The test was stopped, the participant reinstructed, and a new test started if during the first attempt false negative or false positive responses exceeded 50%, or if poor fixation was observed by the practitioner. The subsequent test attempt was not interrupted if poor reliability indices or poor fixation was observed. All cases were used in subsequent analyses.

The SITA Fast 30-2 threshold test was used to evaluate binocular central visual field to 30 deg eccentricity with 76 points spaced 6 degrees apart (Figure 1). The SITA Fast 60-4 threshold test was used to assess the binocular peripheral field from 30 to 60 deg eccentricity with 60 points spaced 12 degrees apart (Figure 1). These grid patterns were chosen as they are familiar to clinicians and arguably a gold standard pattern for visual field assessment used for diagnostic purposes. For the 30-2 assessment, near correction adapted from the habitual distance correction was provided in full aperture trial lenses used in adult half-eye trial frames with lens centration corrected for near. The 60-4 test was performed uncorrected to minimise the possibility of lens and frame artefacts. The purpose of the study was to assess functional visual fields in the most habitual form that was appropriate. Whilst it might be considered that the use of the refractive correction normally used for mobility (including multifocals) would be most habitual, the perimeter used had a working distance of 33cm and therefore assessment with correction incorporating a distance element would have underestimated sensitivity. Instead, the established HFA protocols of using near correction for the central 30 deg and no correction in the 30-60 deg field were used. It should therefore be noted that the results will not reflect variations in visual field sensitivity resulting from refractive correction, such as rim artefacts or near blur from progressive addition lenses.

Analyses

The absolute threshold values from the SITA Fast 30-2 and 60-4 tests were used to calculate mean threshold of the central (0-30 deg) and the peripheral (30-60 deg), and superior and inferior visual field.

Responses to the D-AI were converted to person measures using Rasch analysis (see Appendix 1 for details), where higher person measures indicate greater perceived ability. To determine overall self-reported function, responses to all 43 goals were assessed. Responses to the four goals of the mobility domain (mobility at home, mobility indoors, mobility outdoors, and using public transport) were used to determine self-reported mobility function and were Rasch analysed in isolation.

To investigate the relationship between the predictor variables and self-reported function Mann-Whitney U tests were conducted for the dichotomous predictors to establish whether the means of the independent samples significantly differed, Kruskal-Wallis tests were performed on the nominal/categorical data as a non-parametric determination of differences between the independent groups, and non-parametric 2-tailed Spearman's rho bivariate correlations were conducted to investigate the relationship between the continuous predictor variables and self-reported visual function. A Bonferroni corrected significance level of p=0.0025 (=0.05/20) was used.

To allow for the prediction of self-reported visual function by a linear combination of two or more predictor variables, and to explore the unique variance explained by each predictor variable, clinical function variables were entered into the regression model in a forward stepwise manner using an alpha of 0.05.

Collinearity statistics were assessed to determine whether scores for different visual field areas were independent. These measures included the tolerance and variance inflation factor statistics. Variance inflation factors (VIF) greater than 10,[53] and a tolerance statistic below 0.1[54,55] would indicate a multicollinearity bias.

Results

Fifty two participants took part, and Table 1 illustrates the descriptive statistics for the parameters assessed. All participants were able to complete both visual field tests binocularly. Twelve percent of participants had difficulty either seeing the standard fixation target or maintaining single vision during the assessment. For these participants, a custom fixation target consisting of a black 2mm high contrast pericentral ring around the fixation spot was used to aid fixation. The SITA Fast 30-2 assessment took on average 5 min 14 sec(±11 sec), and the 60-4 took on average 4 min 59 sec(±7 sec). The median threshold values of the sample for each location within the central 30-2 and peripheral 60-4 test programmes are demonstrated in Figure 1.

Table 1. *Descriptive statistics of the variables assessed (n=52). The mean ± standard deviation, and the median (interquartile range) are given for the clinical visual function variables. *Number of comorbid conditions from a list of 12 common medical conditions representing general health status.*[56]

Demographic variables	
Gender (n)	31 (60%)
Male	21 (40%)
Female	
Age (years)	
Median (25% IQ-75% IQ)	61(49-68)
Min-max	31-96
Ocular diagnosis (n)	
RP	21 (40%)
Glaucoma	22 (42%)
Vascular occlusion	2 (4%)
Retinal detachments/tears	2 (4%)
Other	5 (10%)
Duration of visual impairment (years)	
Median (25% IQ-75% IQ)	15(6-26)
Min-max	1-63
Registration status (n)	
Registered severely sight impaired	22 (42%)
Registered sight impaired	6 (12%)
Not registered	24 (46%)
Living arrangements (n)	
Alone	14 (27%)
With partner	33 (63%)
With other	4 (8%)
Warden assisted	1 (2%)
Current employment status (n)	
Working full time	16 (31%)
Working part time	5 (10%)
Student	3 (6%)
Unemployed	1 (2%)
Retired	26 (50%)
Number of prescribed medications (n)	
Median (25% IQ-75% IQ)	2(0.5-2.5)
Min-max	0-11
Number of co-morbidities* (n)	
Median (25% IQ-75% IQ)	2(1-3)
Min-max	0-5
Use of mobility aids (n)	

White cane or guide dog	20 (38%)		
No mobility aids used			
Use of low vision aids (n)	32 (62%)		
Yes	23 (44%)		
No	29 (56%)		
Have you fallen in the past 12months? (n)			
Yes	23 (44%)		
No	29 (56%)		
Clinical function variables	**Mean (±std)**	**Median (25% IQ-75% IQ))**	**Range**
Binocular distance visual acuity (logMAR)	+0.34(±0.09)	+0.07(-0.07-0.46)	-0.22-3.00
Binocular contrast sensitivity (logCS units)	+1.44(±0.08)	+1.63(1.20-1.95)	0.00-1.95
Binocular reading acuity (logMAR)	+0.50(±0.12)	+0.18(0.02-0.41)	-0.13-3.00
Binocular visual field variables			
Overall visual field (0-60 deg; mean threshold, dB)	11.7(±1.4)	11.8(2.1-20.7)	0.0-27.1
Central visual field (0-30 deg; mean threshold, dB)	14.1(±1.6)	13.0(3.1-24.1)	0.0-31.8
Peripheral visual field (30-60 deg; mean threshold, dB)	8.7(±1.1)	7.5(0.0-15.5)	0.0-23.0
Superior visual field (0-60 deg; mean threshold, dB)	11.1(±1.3)	10.2(2.0-19.2)	0.0-27.6
Inferior visual field (0-60 deg; mean threshold, dB)	12.2(±1.4)	8.9(1.9-22.8)	0.0-28.3
Dutch Activity Inventory Person Measures			
Overall self-reported function (logits)	2.09(±0.26)	1.48(0.72-3.40)	-0.52-6.00
Self-reported mobility function (logits)	2.81(±0.46)	1.66(0.21-5.79)	-4.19-7.27

Figure 1. *Threshold values representing the median threshold of the sample (n=52) at each test location for* ***a)*** *central 30-2, and* ***b)*** *peripheral 60-4 tests.*

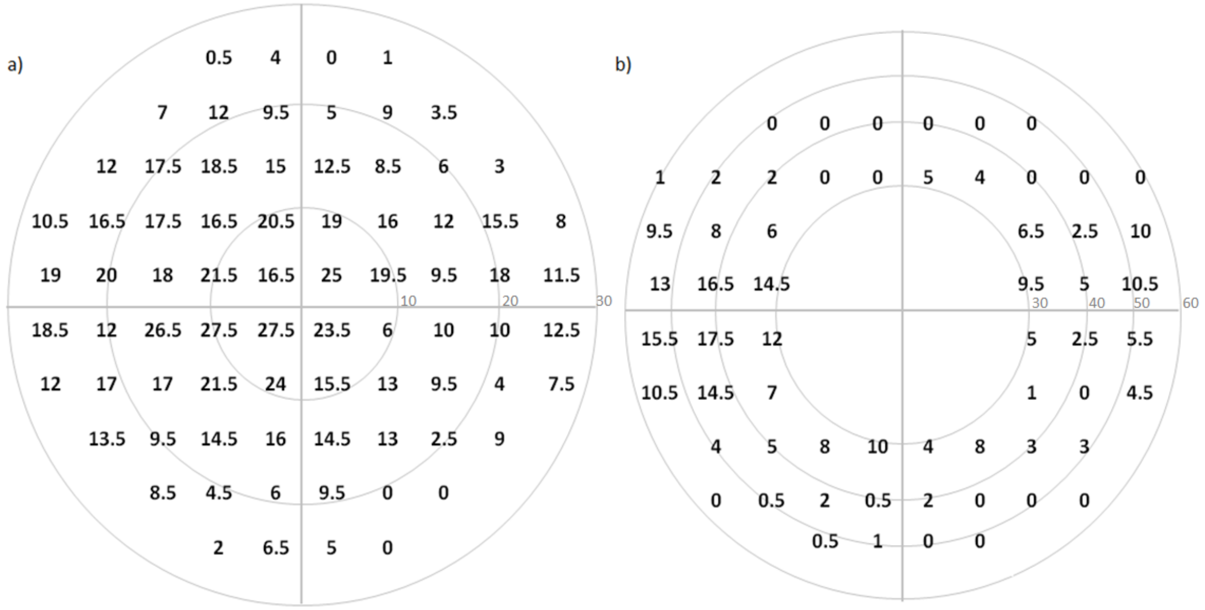

Table 2. *Relationship between the variables assessed, and self-reported overall and mobility function. *p≤0.0025, for all others p>0.0025.*

Demographic variables	**Overall D-AI score**	**Mobility function**
Dichotomous variables (U)		
Gender	U=286.00, p=0.52	U=275.00, p=0.39
Use of mobility aids	*U=112.50, p<0.001	*U=101.50, p<0.001
Use of low vision aids	*U=107.50, p<0.001	U=166.50, p=0.020
Have you fallen in the past 12 months?	U=208.50, p=0.020	U=225.00, p=0.046
Nominal variables (χ^2)		
Ocular diagnosis	χ^2=13.57, p=0.009	χ^2=15.35, p=0.004
Living arrangements	χ^2=0.98, p=0.81	χ^2=1.79, p=0.62
Current employment status	χ^2=2.71, p=0.61	χ^2=2.00, p=0.74
Sight loss registration	*χ^2=26.92, p<0.001	*χ^2=23.66, p<0.001
Continuous variables (R^2)		
Age	R^2=0.03, p=0.23	R^2=0.05, p=0.10
Duration of visual impairment	R^2=0.16, p=0.004	*R^2=0.23, p<0.001
Number of medications	R^2=0.00, p=0.50	R^2=0.01, p=0.52
Number of comorbidities	R^2=0.12, p=0.015	R^2=0.07, p=0.060
Clinical function variables (R^2)		
Distance visual acuity (logMAR)	*R^2=0.52, p<0.001	*R^2=0.40, p<0.001
Contrast sensitivity (logCS units)	*R^2=0.52, p<0.001	*R^2=0.38, p<0.001
Binocular reading acuity (logMAR)	*R^2=0.54, p<0.001	*R^2=0.42, p<0.001
Binocular visual field variables (R^2)		
Overall field (0-60 deg)	*R^2=0.50, p<0.001	*R^2=0.64, p<0.001
Central field (0-30 deg)	*R^2=0.49, p<0.001	*R^2=0.61, p<0.001
Peripheral field (30-60 deg)	*R^2=0.48, p<0.001	*R^2=0.63, p<0.001
Superior visual field (0-60 deg)	*R^2=0.41, p<0.001	*R^2=0.56, p<0.001

Inferior visual field (0-60 deg)	*R^2=0.55, p<0.001	*R^2=0.67, p<0.001

Table 2 shows the relationships between the parameters assessed and the outcome measures of overall self-reported function and self-reported mobility function.

Self-reported overall and mobility related function were significantly worse for individuals who reported using mobility aids than for those who did not (U= 112.50, p<.0001 and U=101.50, p<.0001 respectively), and for those with more severe visual impairment as indicated by their visual registration status (R^2=0.50 p<.0001; R^2=0.45 p<.0001 respectively). Overall self-reported function was more difficult for participants who reported using low vision aids than those who did not (U=107.50, p<.0001). Longer duration of visual impairment was a significant predictor of worse self-reported mobility function (R^2=0.23, p<.0001). Acuity and contrast sensitivity variables all correlated significantly (p≤0.0025) with overall and mobility related self-reported visual function, where worse visual function measures were associated with worse perceived function.

Greater visual field loss (0-60 deg) was associated with worse self-reported overall function (R^2=0.50; p<.0001). Worse overall binocular visual field was in particular a good predictor of greater self-reported difficulty in mobility related activities (R^2=0.64, p<.0001).

Splitting the visual field into central (0-30 deg) and peripheral (30-60 deg) areas, the relationship between the visual field and self-reported function did not appear to be greatly dependent on eccentricity. The peripheral (30-60 deg) and central (0-30 deg) visual field were similarly correlated with self-reported function for both overall function (R^2=0.49, p<.0001 central and R^2=0.48, p<.0001 peripheral) and mobility related function (R^2=0.61, p<.0001 central and R^2=0.63, p<.0001 peripheral), where greater visual field loss is associated with worse perceived function. The superior and inferior visual field areas were also similarly related to overall (R^2=0.41, p<.0001 superior and R^2=0.56, p<.0001 inferior) and mobility related function R^2=0.55, p<.0001 superior and R^2=0.67, p<.0001 inferior), but with a tendency for the inferior fields to be better correlated to perceived function.

Although there was a strong correlation between the central (0-30 deg) and the peripheral (30-60 deg) visual field scores (R^2=0.85, p<.0001), and between the superior and inferior visual field scores (R^2=0.85, p<.0001), further investigation suggested these relationships were unlikely to adversely affect the results obtained by including both variables in subsequent multiple regression analyses due to multicollinearity. Variance inflation factors were lower than required at 5.85 and 4.29[53] and the tolerance statistics of 0.17 and 0.23 were greater than required.[54,55] Therefore, although thresholds are related to one another, the relative roles of the central (0-30 deg) and peripheral (30-60 deg) field, and of the superior and inferior field in reflecting functional difficulty can be appropriately investigated with regression analyses.

The variables of central (0-30 deg) and peripheral (30-60) visual field mean thresholds, binocular visual acuity, and binocular contrast sensitivity were entered into stepwise multiple regressions to determine which independently explained significant amounts of variance in overall and mobility self-reported function (Table 3a). The peripheral (30-60 deg) visual field was found to account for most variance (50%) in overall self-reported function. Also significant in this model was binocular contrast sensitivity, which explained a further 9% of variance. For self-reported mobility function, the peripheral (30-60 deg) visual field explained 59% of the variance in self-reported mobility function. When combined with binocular contrast sensitivity this increased to 67%.

Further stepwise regression analyses were conducted including the superior and inferior visual field mean thresholds, binocular visual acuity, and binocular contrast sensitivity (Table 3b). The inferior visual field explained 54% of overall self-reported function, and 61% when combined with binocular contrast sensitivity. The inferior visual field was also found to account for most variance (61%) in self-reported mobility function. Binocular contrast sensitivity explained a further 7% of variance.

Table 3. *Results of stepwise regression analyses to determine which clinical function variables best represent overall self-reported function, and mobility function (n=52). Variables included: a) central (0-*

30 deg) and peripheral (30-60 deg) visual field, contrast sensitivity, distance visual acuity; b) superior and inferior visual field, contrast sensitivity, distance visual acuity. B= unstandardized regression coefficients, SE B= standard errors, β= standardised regression coefficients, R^2 change= amount of additional variance by including predictors from sample.

a	**B**	**SE B**	**β**	**R^2 change**	**p**
Overall D-AI score					
Peripheral (30-60 deg) field	0.12	0.03	0.51	0.50	<0.001
Binocular CS	1.11	0.33	0.36	0.09	0.002
R^2	0.59				
Mobility function					
Peripheral (30-60 deg) field	0.24	0.04	0.58	0.59	<0.001
Binocular CS	1.83	0.53	0.34	0.08	0.001
R^2	0.67				
b	**B**	**SE B**	**β**	**R^2 change**	**p**
Overall D-AI function					
Inferior visual field	0.10	0.02	0.56	0.54	<0.001
Binocular CS	0.99	0.33	0.32	0.07	0.004
R^2	0.61				
Mobility function					
Inferior visual field	0.19	0.03	0.61	0.61	<0.001
Binocular CS	1.68	0.53	0.31	0.07	0.002
R^2	0.68				

Discussion

The aim of this study was to investigate which areas of the binocular threshold visual field should be measured in order to best reflect self-reported function. Both central (0-30 deg) and peripheral (30-60 deg) mean thresholds related well to self-reported function (Table 2), but it was the peripheral (30-60 deg) field that was the best predictor of both overall and mobility related self-reported function in this sample (Table 3a). Therefore, in order to accurately determine the functional consequences of visual field loss, the peripheral visual field should also be considered.

That the peripheral visual field is important for mobility function is supported by previous findings using several different outcome measures. In a sample of older adults, the status of peripheral visual field (20-60 deg) was significantly correlated with the risk of falling, whereas the central visual field (0-20 deg) was not.[57] Also, correcting for central visual impairment alone may be insufficient to effectively decrease rates of falls relating to visual impairment.[58] Monocular kinetic visual field extent in people with Retinitis Pigmentosa has also been found to be significantly associated with mobility function as assessed on a mobility course, with worse function in subjects with fields contained within the central 20 deg.[59] Orientation and mobility performance has been shown to be worse when the visual field loss is peripheral than when the loss is central,[60] with an increased risk of tripping over obstacles also associated with peripheral visual impairment.[28] The relationship between visual field loss and function is also likely to be influenced by compensatory scanning behaviour used by individuals with visual field loss which may improve task performance. [61-64]

Other studies have indicated that the central visual field is more strongly related to mobility function, however. The field of view required for navigation in subjects with artificially restricted fields is between 10.9 and 32.1 deg depending on contrast conditions.[34] It has been proposed that the central 37 deg is most important for mobility function in individuals with low vision,[29] and Tabrett and Latham[13] found the central 10-30 deg best predicted visual related activity limitation in mobility tasks (although fields were not assessed beyond 30 deg). In subjects with glaucoma, perceived mobility function was best explained by the function of the inferior 5 deg from fixation.[65]

The variance in findings of these studies is likely attributed to differences in the methods of assessing the visual field, and how mobility is assessed. Several previous studies have assessed the visual field binocularly using kinetic paradigms that include the peripheral visual field,[28,29,31,32] while others have used threshold techniques restricted to the central 30 deg visual field.[13,30,52] Only the present study has considered threshold fields beyond 30 deg. In terms of mobility, some studies have used falls as an outcome measure,[57,58] others have used objective performance on mobility courses,[28-34] while others including the present study have used questionnaires to assess perceived function.[1,13,21,22,24] Since it has been suggested that the different areas of the visual field are used for different purposes in mobility, with the central field used to guide walking and the peripheral field used to establish and update an accurate representation of spatial structure for navigation,[66] relationships between field and mobility may depend on the specific mobility issues that the outcome measure used taps into.

The results of this study also support the significance of the inferior visual field for mobility function that has been previously demonstrated.[28,29,36-39] Visual field loss in the inferior mid-periphery (20 – 40 degrees) has been shown to adversely affect mobility more than loss of the visual field in other areas.[29] Similarly, visual field loss in the lower peripheral region has shown comparable decrements in walking speed on a mobility course.[28,39] The inferior visual field has also been shown to relate significantly to perceived mobility function.[36] One potential reason for the increased importance of inferior field in mobility is that the inferior field may provide a stronger contribution to postural stability than the superior visual field.[37] It has also been suggested that the inferior visual field contributes a greater proportion of the visual information used in determining lower limb movements, foot placement, and obstacle detection.[39] Individuals tend to fixate approximately two steps ahead when walking,[67] but loss of information from the lower visual field results in reduced step length when walking across uneven terrain.[39]

It should be noted that previous studies demonstrating the importance of the inferior visual field for mobility function have assessed subjects whose degree of visual field loss was likely less than that of many of the participants in our sample. Over half of the current sample were registered sight impaired (Table 1), and although this may relate to visual acuity rather than fields, individuals with visual field loss were recruited, and Table 1 shows a relatively good median acuity, suggesting visual field loss was the primary reason for registration. Previous studies have evaluated older adults with no visual impairment[28,29], normally sighted subjects with simulated field loss,[39] participants with glaucoma,[36,37] and a mixed sample with half the participants having visual impairment.[29] In the present study we have demonstrated that loss in the inferior visual field remains a better indicator of perceived mobility function than the superior field in individuals with a greater degree of established visual impairment.

While the association between the inferior visual field and mobility is well documented, the significance of the inferior visual field to overall function has not previously been investigated. The inferior visual field was also selected as the primary predictor of overall perceived function in the present study, indicating the significance of the inferior visual field for general function. This could be explained by the presence of more ecologically relevant information in this region of space.[68]

A further predictor of overall and mobility self-reported function was binocular contrast sensitivity. This supports previous research that has shown that while visual acuity, visual field, and contrast sensitivity correlate significantly with mobility performance, the visual field and contrast sensitivity are stronger predictors than visual acuity.[60,69-71] The combined effect of visual field and contrast sensitivity in other studies of low vision groups has been shown to account for between 39% and 64% of the variance in measured mobility performance,[32,59,72] similar to the 59-67% found here.

Whilst this study assesses binocular static thresholds to 60 deg eccentricity, previous studies have assessed the binocular visual field past 30 deg with suprathreshold or kinetic paradigms. In people with glaucoma, the Esterman suprathreshold field test has been shown to relate well to self-reported function in some studies[23,24] but not in others.[22,25,26] Other studies have found an association between the visual field assessed kinetically and self-reported function,[1,31] and mobility performance.[29,31-33] Whether a binocular threshold visual field is a more appropriate way to assess functional field loss is not clear as few studies to date have compared different visual field strategies and their ability to reflect functional loss. One study did not find significant differences in how well different visual field protocols related to self-reported function,[73] whereas another found that of several visual field protocols only the Esterman field score correlated with self-reported function.[74] It is yet to be determined whether a threshold binocular visual field test assessing both central and peripheral field could yield stronger correlation with functional ability than other methods of visual field assessment, although the extent of variance explained in the present study is promising.

In the present study, a cohort with a wide range of visual field sensitivities from mild to profound loss were assessed in order to examine the relationship between field loss and functional ability. In future work, a larger sample and inclusion of a normally sighted cohort may be needed to provide robust regressions and to examine the ability of any proposed functional field test to discriminate between people with and without field loss. Alternative considerations of multicolinearity in the data might also need to be considered. The use of a single self-reported outcome provides a broad indication of general mobility function, but does not explore specific mobility tasks. These broad mobility goals are however less likely to be biased by field area-specific tasks such as tripping over obstacles or walking into overhanging objects.

In conclusion, peripheral and central fields both have a role in reflecting the functional difficulties of people with field loss and should be considered in a functional visual field assessment. The significance of the inferior field to both mobility function and overall function has also been demonstrated in individuals with moderate to severe visual field loss. A binocular threshold test that assesses to 60 deg can represent the functional abilities of individuals with peripheral visual impairment. However, what remains to be determined is whether a threshold method is preferable to alternative paradigms such as suprathreshold or kinetic fields in producing an outcome that can be used clinically and best describes functional difficulty. Further research will determine the most appropriate method of assessing visual fields in the low vision assessment by comparing different visual field protocols.

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Appendix 1

Calculation of Person Measures with Rasch analysis

Methods

Summing the ordinal scores of items derived from Likert scales to give an overall score makes no allowance for the varying difficulties of different items, and therefore converting the ordinal responses to interval data in Rasch analysis is indicated[1]. This allows analysis of the instrument's performance to be investigated[2], and for the derived interval data to be used to comment on the ability of individual participants (person measures) and the difficulty of individual items (item difficulties).

Rasch analysis of the data was undertaken with Winsteps (version 3.91.0; winsteps.com), using a single Andrich rating scale model[3]. Person and item measures are produced in logits, or log odds units, which represent the likelihood of a person having the ability to achieve an item, or an item being achievable for a person. Responses to the D-AI were scored according to the following scale: 0 = not important or not applicable (considered as missing data), 5= no difficulty, 4=slight difficulty, 3=moderate difficulty, 2 = severe difficulty, 1=impossible without help. As detailed in Table 4, only 10 goals were applicable to less than 80% of the sample. Higher derived person measures therefore reflect higher ability, and higher item difficulties indicate a greater ability required to achieve the item, i.e. a 'harder' item.

Initially, category thresholds were examined to determine if all categories were utilised, that categories were used in order of functional ability, and that each category was the most probable response at some point on the ability scale. The reliability indices of the resulting instrument were assessed in terms of person separation statistics, which provide an indication of the instrument's ability to discriminate between respondents: person separation and person reliability should be greater than the suggested minima of 2.0 and 0.80 respectively[4] . Further, item separation statistics provide an indication of how reliably ordered the items are in terms of difficulty: item separation and item reliability should be in excess of suggested minima of 3.0 and 0.90[4]. Targeting, or the difference between mean item and person measures, should ideally be less than 1.0 logit[5,6].

Consideration of how well the items in the scale fit a unidimensional construct and assesses a single latent trait is important to assess, and was addressed in two ways. In Rasch residual-based principal components analysis (PCA), the variance in the data that is accounted for by the Rasch dimension is first considered, with at least 60% of variance explained by the primary measure considered to demonstrate reasonable overall unidimensionality in the instrument[5,6]. The unexplained variance or residuals are then decomposed to look for patterns that may indicate a secondary dimension to the data rather than random noise. Contrasts found within the residuals after the primary model has been extracted that have at least the strength of two items, i.e., an eigenvalue of at least 2.0 may be considered as evidence that an instrument does not assess a strictly unidimensional construct[7].

Additionally, the fit of individual items to a unidimensional construct is assessed. It is considered that items with infit and outfit meansquare (mnsq) values within a range of 0.5 to 1.5 contribute usefully to a scale[8]. Items with mnsq values greater than two have the potential to damage the integrity of the scale[8].

Since most participants had either RP (n=21) or glaucoma (n=22), differential item functioning (DIF) by ocular diagnosis was also considered to determine whether any item was answered differently depending on the ocular condition of the participant. DIF was considered as significant if the difference in item difficulty between groups (DIF contrast) was greater than 0.5 logits, and was significant at the 1% level[9].

Results

Person measures for overall self-reported function were derived from the data set directly, using all 43 goals assessed. Category functions were ordered (Andrich thresholds none, -

0.86, -0.51, 0.51 and 0.86), each of which was the most probable response at some point on the scale. Person separation was 2.51 (reliability 0.86), and item separation was 3.06 (reliability 0.90), indicating that the instrument ranks both people and items acceptably. Targeting was +2.09±1.86 logits, poorer than the ideal and indicating that this sample has a higher ability, on average, than the instrument is aimed at. No item showed significant DIF by ocular diagnosis, indicating that the questions were responded to in a similar way by those with RP and with glaucoma.

Only 54% of variance is explained by the primary measure, slightly lower than the ideal. As expected due to wide ranging nature of the instrument, and as found in the original Rasch validation[9], there are five significant contrasts, with the largest having a strength of 5.2 eigenunits. There are some misfitting items (Table 4), with six items with fits in the range 1.5-2.0 and a further two with fits greater than two (outfits of 2.18 and 2.36). The lack of exact fit might be due to lower subject numbers than in the previous analysis. In large part, the relatively poor fits can be considered acceptable and do not diminish the validity of the measures (Linacre M., personal communication, 2015).

However, to investigate further whether misfitting items should be excluded from the analysis, the analysis was repeated with misfitting items removed. Initially, the two items with outfits greater than 2 were excluded. All items then had fits in the range 0.5-2.0, but other parameters were similar (person separation 2.44, item separation 2.89, targeting 2.08±1.90, variance explained by the primary measure 53%, 5 contrasts greater than 2 eigenunits). Person measures with the 41 item instrument were not different from those with the 43 item instrument ($t(51)=0.54$, $p=0.60$). A further reanalysis iteratively removed items with greatest misfit until all items fell in the range 0.5-1.5. Twenty four items remained in the instrument after this process. The variance explained by the primary measure rose to 57% and the number of contrasts fell to three, with a maximum value of 3.2 eigenunits. However, reliability measures remained similar (person 2.09, item 3.13), and the number of participants achieving a ‘maximum measure' (i.e. reporting 'no difficulty' to any item) rose from five in the 43 item instrument to 14 in the 24 item instrument. All analyses presented were repeated with person measures derived from the 41 and 24 item instruments, and no differences in the parameters identified were found.

Therefore, whilst the item reduced instruments might represent a more rigorous interpretation of unidimensional difficulties with activities of daily living in this sample, the 41 item instrument results in person measures that are no different from the full instrument, and the 24 item instrument reduces the range of visual activities considered to a point that the scale might not be considered to represent overall function. In the results presented, the 43 item instrument is therefore used (Table 5). It was considered that keeping the range of activities of daily living included in the questionnaire as broad as possible was important, and using this analysis also allows comparability of the questionnaire between this study and previous analysis[9].

To represent self-reported difficulty with mobility function, the four goals underpinning the 'mobility' objective (mobility at home, mobility indoors, mobility outdoors, and using public transport) were Rasch analysed in isolation. Andrich category thresholds were none, -3.29, -1.24, 0.52 and 4.00, and each category was the most likely choice at some point on the scale. Person separation was 2.33 (reliability 0.84), item separation was 6.14 (reliability 0.97), and all fit values fell within the range 0.5-1.5. Targeting was +2.81±3.26 logits. The variance explained by the primary measure was 75%, and there were no significant contrasts. Person measures derived from this analysis were therefore used to represent self-reported mobility function.

Table 4. *Item parameters of the 43 goals of the Dutch ICF Activity Inventory as determined by Rasch analysis. Goals are ordered by item difficulty, with the most difficult item first. Infit and oufit mnsq values, indicating the fit of the item to the underlying unidimensional construct are given. Applicability indicates the number of participants (max n=52) to whom the item was important or applicable.*

Goal	Domain	Item difficulty	SE	Infit mnsq	Oufit mnsq	Applicability
Applying for a job	Major life areas	1.31	0.23	1.18	0.97	24
Doing general maintenance tasks at home	Domestic life	1.10	0.23	1.22	1.50	26
Mobility indoors	Mobility	1.10	0.16	0.52	0.79	52
Doing laundry	Domestic life	0.95	0.18	0.96	1.22	44
Mobility outdoors	Mobility	0.92	0.16	1.02	1.43	52
Using public transport	Mobility	0.79	0.16	0.54	0.45	52
Shopping	Domestic life	0.79	0.16	0.85	0.69	52
Physical activity and / or sport	Community, social and civil life	0.66	0.20	1.07	1.28	37
Reading	Learning and applying knowledge	0.65	0.16	1.05	1.48	52
Social events	Community, social and civil life	0.57	0.17	0.85	0.79	52
Writing	Learning and applying knowledge	0.54	0.17	1.34	1.28	52
Following a schedule and getting to appointments on time	General tasks and demands	0.54	0.17	0.99	0.76	52
Holidays and trips	Community, social and civil life	0.53	0.17	0.61	0.49	50
(Grand) child care	Domestic life	0.51	0.25	1.08	2.36	25
Grocery shopping	Domestic life	0.51	0.17	0.66	0.54	50
Working activities	Major life areas	0.47	0.20	0.95	0.78	39
Watching TV	Learning and applying knowledge	0.43	0.17	0.82	0.73	52
Accessibility at work, such as moving around and using facilities	Major life areas	0.43	0.20	0.86	0.64	38
Dining out	Community, social and civil life	0.41	0.17	0.43	0.44	51
Participating in Education	Major life areas	0.26	0.29	0.76	0.57	15
Interaction with strangers	Interpersonal interactions and relationships	0.25	0.17	1.18	0.90	52

Health care for another adult	Domestic life	0.19	0.46	0.87	0.52	13
Prepare your usual daily meals	Domestic life	0.13	0.18	0.97	0.70	50
Interaction with colleagues	Interpersonal interactions and relationships	0.11	0.21	1.29	1.04	38
Dealing with personal correspondence	Communication	-0.10	0.19	1.42	1.46	52
Withdrawing money and paying	Domestic life	-0.10	0.19	1.29	1.00	52
Using a computer	Communication	-0.20	0.21	1.3	1.65	47
Getting information	Major life areas	-0.25	0.19	1.74	1.3	52
Following a schedule and getting to appointments on time	General tasks and demands	-0.33	0.20	1.43	1.11	52
Communicating with people face to face	Interpersonal interactions and relationships	-0.33	0.20	1.24	0.99	52
Managing finances, such as reading accounts or filling in a form	Major life areas	-0.33	0.20	1.71	1.32	52
Cleaning and tidying up	Domestic life	-0.45	0.22	1.57	0.98	47
Pet care	Domestic life	-0.46	0.33	1.01	0.72	18
Relationship with loved ones	Interpersonal interactions and relationships	-0.58	0.22	1.23	0.87	52
Mobility at home	Mobility	-0.68	0.22	0.76	0.60	52
Recreational / leisure time activities	Community, social and civil life	-0.73	0.23	1.60	1.15	52
Having visitors	Community, social and civil life	-0.78	0.23	0.54	0.48	52
Using a telephone	Communication	-1.02	0.26	1.45	1.66	52
Eating and drinking	Self care	-1.24	0.28	0.95	0.48	52
Personal health care and medication	Self care	-1.40	0.3	0.92	0.49	52
Dressing	Self care	-1.50	0.32	0.83	0.44	52
Following the news	Community, social and civil life	-1.50	0.32	1.28	1.14	52
Personal hygiene	Self care	-2.18	0.44	0.83	2.18	52